SEMIANNUAL REPORT TO NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RE: "An Evaluation of Possible Relationships Between Solar Activity and Tree-Ring Growth in Western North America"

(NGR 03-002-101)

January - 1967

Prepared by
Harold C. Fritts
Laboratory of Tree-Ring Research
University of Arizona

This report describes the four different phases of our Solar Relationships study. 1) A new program for prewhitening tree-ring series has been developed. 2) The processing of new long-term chronologies has been initiated. 3) Tests of normality have been completed and tests of stationarity have been designed. 4) A variety of analyses and programs designed to probe for periodicities and solar-relationships in ring-data have been initiated, and many results have already been compiled and plotted.

1) Development of a New Tree-Ring Index Program

The early phases of our solar relationship study were directed to improving our quantitative tree-ring processing procedures which generate long and homogeneous chronologies. We reprogrammed our tree-ring index program to fit a more flexible growth curve. This program is now being employed to reprocess a large backlog of dated ring series which are necessary for future analysis of solar relationships. In statistical terms, the Index Program removed the gradually changing growth function or red noise and essentially prewhitens the chronology.

Since we were able to assign our programmer almost exclusively to this task when she started work on September 15, she was able to organize our entire programming facility as well as to alter, debug, and test this new program. As a result, we have a large battery of operational programs, one publication to show for our efforts, and are moving rapidly into other phases of our solar relationship work.

The NASA technical supervisor for this effort is Charles C. Dalton, Aerospace Environment Division, Aero-Astrodynamics Laboratory, Marshall Space Flight Center, Huntsville, Alabama.

The paper is entitled "A Revised Computer Program for Standardizing Tree-Ring Series" by Christine P. Bottorff, James E. Mosimann, and Harold C. Fritts and will be submitted to the Tree-Ring Bulletin after approval by N.A.S.A.

2) Processing of Long-Term Chronologies

Since many of our existing climatic chronologies were laboriously derived by means of hand calculations, many man-years of work were consumed in their development. As a result, chronologies were widely scattered over North America (see Figure 1) and many had not been brought up to date for 20 to 30 years. Since 1965, the staff of the Laboratory of Tree-Ring Research have been collecting and dating new materials from throughout North America (NSF Grant GP-4640).

Because of the immediate need for up-to-date and objectively derived chronologies in our proposed Solar Relationship time series analyses, a portion of our data processing effort has been aimed at catalyzing the analysis of these data. Therefore, with our new index processing program and the newly developed chronologies, we are rapidly collecting extensive and high quality data for the following two phases as well as new aspects of our solar relationship work.

3) Tests of Normality and Stationarity

A Chi Square test for goodness of fit (see appendix) has been programmed and run on approximate 100-year segments of about 75 different tree-ring chronologies. Approximately 10% of the cases exhibit non-normality (significant at the 5% level), and only one exhibits a significance at the 1% level. This test is now routinely made on all new climatic tree-ring chronologies. It would appear that some slight non-normality does sometimes exist in tree-ring data, but it is not sufficiently prevalent to introduce serious error to our present anticipated analyses.

A test for stationarity has been designed but the analysis must await the processing of several specific chronologies as they go through phase 2 of our study.

4) The Search for Tree-Ring, Solar, and Climatic Relationships

So far we have concentrated on the following types of analyses of our older tree-ring chronologies shown in Figure 1.

a) Power and cross-power spectra analyses have been systematically run on 17 chronologies. Chronologies were treated as a Pacific transect (Stations 6, 8, 12, 22, 15, 16, 19, 21, Fig. 1) and a Rocky Mountain transect (Stations 4, 10, 13, 14, 23, 17, 18, 20, 26, Fig. 1). Powers were run for all chronologies as well as for sunspot numbers for the years 1750 through 1930 on the Pacific transect and 1750-1949 on the Rocky Mountain transect.

Cross-power was run between each station in each transect and between each station and sunspot numbers. Since optimum procedures had not been previously determined, we carried calculations out to both 22 and 44 lags and tried analyses assuming a one-year lag and no lag in the sunspot-tree growth relationships. We also ran an analysis identical to one processed at Huntsville to check for possible discrepancies in programs. The results of the two analyses diverge at the extreme high and low frequencies. Plots of all analyses are near completion and await thorough evaluation. It is evident from a brief survey of the plots that noise may create problems in our interpretation and make conclusive statements from these particular analyses difficult. Some reconsideration of the strengths and weaknesses of power spectrum analysis is in order. On the other hand, we believe that with new chronologies and with improved methods of analysis, we should obtain more promising results in the future.

b) A first differences and serial correlation program (see appendix) has been developed to analyze the amplitude and phase of the biennial oscillation (26-27 month fluctuation found in the tropical atmosphere) which might be reflected in tree-ring width variation. The analysis provides a test for possible modulation by lunar phases which might be confused with sunspot relationships. The study is in cooperation with Dr. J. Murray Mitchell and Mr. Glenn Brier, of E.S.S.A.

c) The 26 chronologies shown in Fig. 1 have been filtered with a low pass, a high pass, and an 11-year band pass numerical filter and correlated with a similarly filtered sunspot series. The correlations were plotted on maps and both the 11-year band and low pass results show certain regions in North America which exhibit a direct and inverse response.

Some of the striking relationships exhibited by these results also appear in the cross-power analysis. A combination of both filtering and cross-power spectrum techniques may prove helpful.

General Progress

Although we have encountered continuing difficulty in finding personnel with the breadth of training necessary for this interdisciplinary study, we are continuing our efforts to recruit highly qualified scientists. While we have not been able to hire a statistical-meteorologist, we are receiving contributed statistical consulting services from Dr. P. K. Bhattacharya, Department of Mathematics,and Dr. Chester Kisiel, Department of Hydrology, at the University of Arizona. Dr. Bhattacharya has been studying the theoretical problems of prediction in time series analysis and reports continuing progress in his work. We also encountered considerable interest among several prominent professionals in government service who were working on related problems.

In order to encourage this interest and to help direct some of it toward the solution of our problems, we invited six scientists to a work session with us at the University of Arizona for the period from March 15 - April 15. Five have accepted: Dr. J. Murray Mitchell, Jr., E.S.S.A., Silver Spring, Maryland; Mr. Glenn W. Brier, E.S.S.A., Silver Spring, Maryland; Dr. Paul R. Julian, N.C.A.R., Boulder, Colorado; Mr. Lyle R. Dickey, N.A.S.A., Huntsville, Alabama; and Mr. Charles C. Dalton, also from N.A.S.A., Huntsville. We anticipate hearing from Mr. Dana K. Bailey, E.S.S.A., Boulder, Colorado,within a few weeks. This session will undoubtedly provide considerable impetus and new direction to our work.

APPENDIX

1) First Differences Program

Reads in tree-ring indices for a given period of years and calculates the first differences by the formula $D_i = X_{i+1} - X_i$. These differences are then smoothed over a 4 year period by the formula $X_{i+3} = (D_j + 2D_{j+1} + 3D_{j+2} + 2D_{j+3} + D_{j+4})/9$.

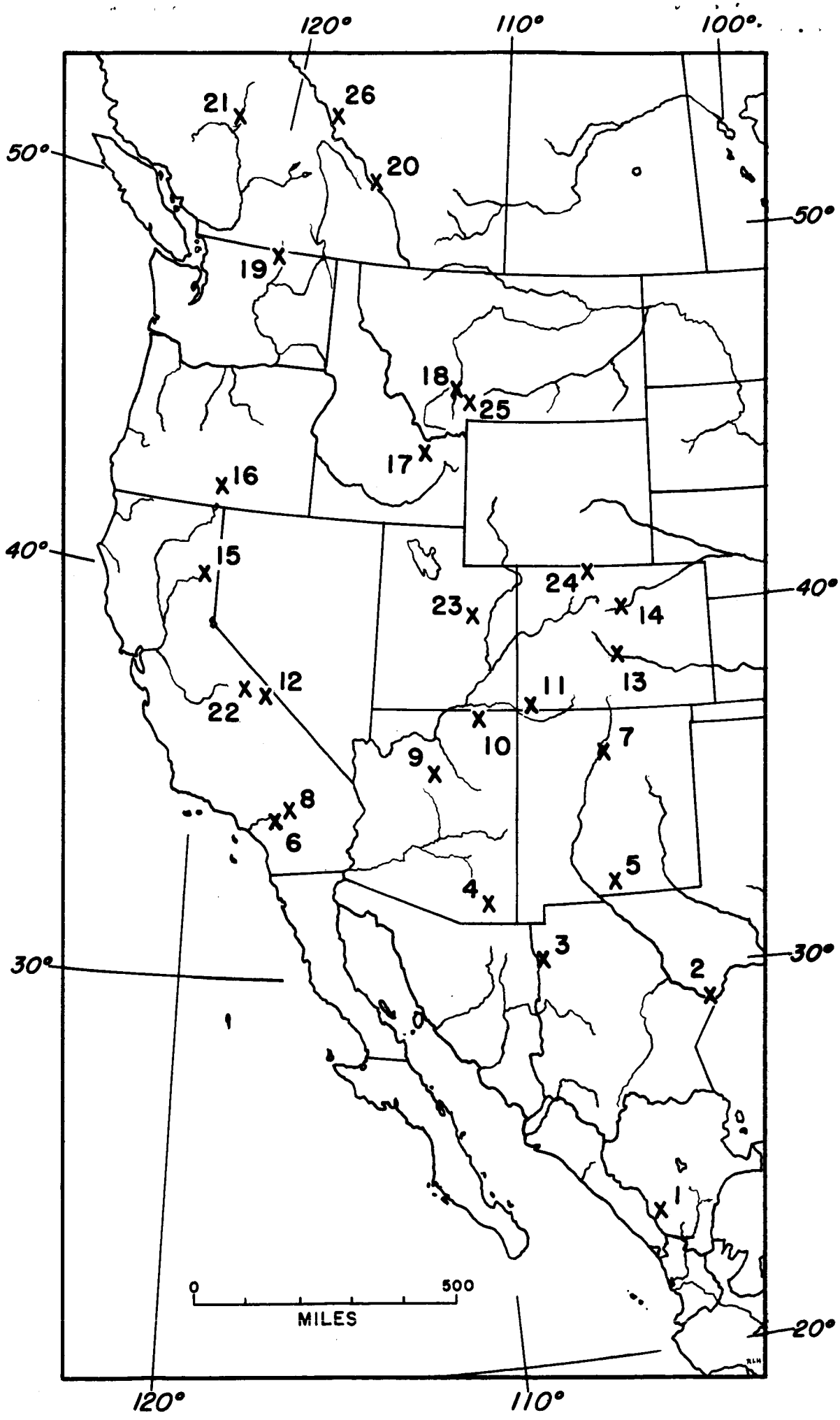
The serial correlation is calculated up to a maximum lag of n - 10 (where n is the length of the series) or 310, whichever occurs first. The printed output includes the tree-ring indices, the smoothed data, and the serial correlation coefficients.

2) Chi-Square Test Program

Performs the chi-square test for goodness of fit to determine whether the distribution about the mean of index values of a series conforms to a normal distribution. It determines and prints whether the deviation of the index values from the theoretical normal distribution is nonsignificant, significant (.05 level), or highly significant (.01 level). It also prints the actual frequency (number) of the indices in certain intervals, the theoretical frequency according to the normal curve, the difference between the two frequencies, difference squared, and the chi-square value.

LEGEND TO FIGURE

Fig. 1. The location and identification number of tree-ring chronologies now available for current analysis. New materials will strengthen and bring these chronologies up to date as well as provide data for new areas and better coverage of western North America.


120°
110°
100°
50°
40°
30°
20°
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
0
500
MILES